

NE/SA/SE5205 Wide-band High-Frequency Amplifier

Product Specification

Linear Products

DESCRIPTION

The NE/SA/SE5205 is a High Frequency Amplifier with a fixed insertion gain of 20dB. The gain is flat to ± 0.5 dB from DC to 450MHz, and the -3dB bandwidth is greater than 600MHz in the EC package. This performance makes the amplifier ideal for cable TV applications. For lower frequency applications, the part is also available in industrial standard dual in-line and small outline packages. The NE/SA/SE5205 operates with a single supply of 6V, and only draws 25mA of supply current, which is much less than comparable hybrid parts. The noise figure is 4.8dB in a 75 Ω system and 6dB in a 50 Ω system.

Until now, most RF or high frequency designers had to settle for discrete or hybrid solutions to their amplification problems. Most of these solutions required trade-offs that the designer had to accept in order to use high frequency gain stages. These include high power consumption, large component count, transformers, large packages with heat sinks, and high part cost. The NE/SA/SE5205 solves these problems by incorporating a wide-band amplifier on a single monolithic chip.

The part is well matched to 50 or 75 Ω input and output impedances. The Standing Wave Ratios in 50 and 75 Ω systems do not exceed 1.5 on either the input or output from DC to the -3dB bandwidth limit.

Since the part is a small monolithic IC die, problems such as stray capacitance are minimized. The die size is small enough to fit into a very cost-effective 8-pin small-outline (SO) package to further reduce parasitic effects. A TO-46 metal can is also available that has a case connection for RF grounding which increases the -3dB frequency to 650MHz. The metal can and Cerdip package are hermetically sealed, and can operate over the full -55°C to +125°C range.

No external components are needed other than AC coupling capacitors because the NE/SA/SE5205 is internally compensated and matched to 50 and

75 Ω . The amplifier has very good distortion specifications, with second and third-order intermodulation intercepts of +24dBm and +17dBm respectively at 100MHz.

The device is ideally suited for 75 Ω cable television applications such as decoder boxes, satellite receiver/decoders, and front-end amplifiers for TV receivers. It is also useful for amplified splitters and antenna amplifiers.

The part is matched well for 50 Ω test equipment such as signal generators, oscilloscopes, frequency counters and all kinds of signal analyzers. Other applications at 50 Ω include mobile radio, CB radio and data/video transmission in fiber optics, as well as broad-band LANs and telecom systems. A gain greater than 20dB can be achieved by cascading additional NE/SA/SE5205s in series as required, without any degradation in amplifier stability.

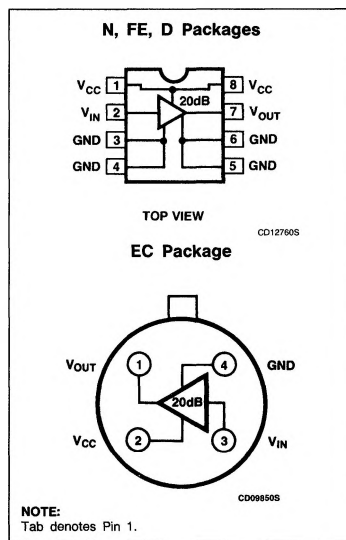
FEATURES

- 650MHz bandwidth
- 20dB insertion gain
- 4.8dB (6dB) noise figure
 $Z_0 = 75\Omega$ ($Z_0 = 50\Omega$)
- No external components required
- Input and output impedances matched to 50/75 Ω systems
- Surface mount package available
- Excellent performance in cable TV 75 Ω systems

APPLICATIONS

- 75 Ω cable TV decoder boxes
- Antenna amplifiers
- Amplified splitters
- Signal generators
- Frequency counters
- Oscilloscopes
- Signal analyzers
- Broad-band LANs
- Fiber-optics
- Modems
- Mobile radio
- CB radio
- Telecommunications

PIN CONFIGURATIONS



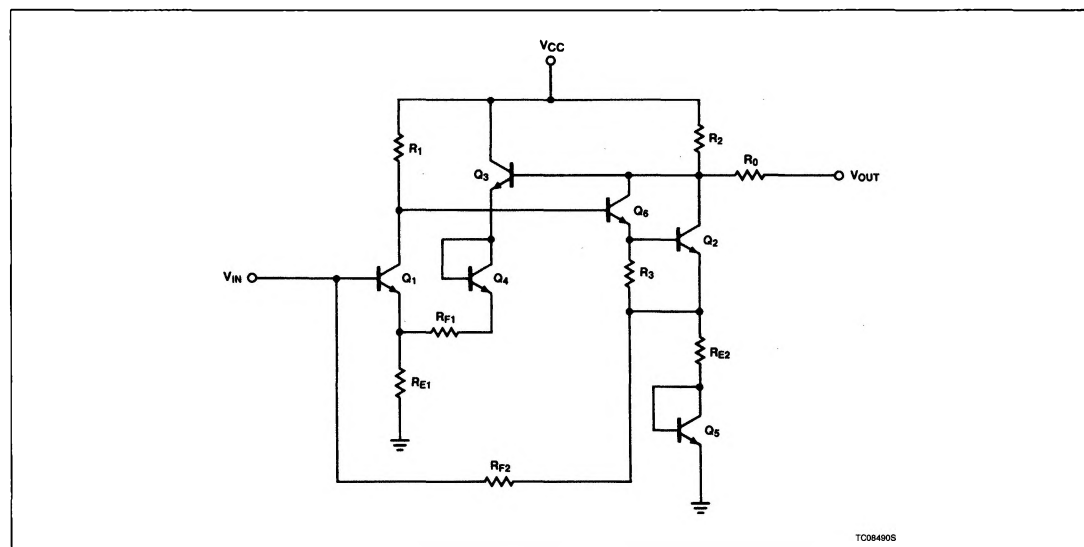
Wide-band High-Frequency Amplifier

NE/SA/SE5205

ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE
8-Pin Plastic SO	0 to +70°C	NE5205D
8-Pin Metal can	0 to +70°C	NE5205EC
4-Pin Cerdip	0 to +70°C	NE5205FE
8-Pin Plastic DIP	0 to +70°C	NE5205N
8-Pin Plastic SO	-40°C to +85°C	SA5205D
8-Pin Plastic DIP	-40°C to +85°C	SA5205N
8-Pin Cerdip	-40°C to +85°C	SA5205FE
8-Pin Cerdip	-55°C to +125°C	SE5205FE

EQUIVALENT SCHEMATIC



Wide-band High-Frequency Amplifier

NE/SA/SE5205

ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNIT
V _{CC}	Supply voltage	9	V
V _{AC}	AC input voltage	5	V _{P-P}
T _A	Operating ambient temperature range NE grade SA grade SE grade	0 to +70 -40 to +85 -55 to +125	°C °C °C
P _D	Maximum power dissipation, T _A = 25°C (still-air) ^{1, 2} FE package N package D package EC package	780 1160 780 1250	mW mW mW mW

NOTES:

1. Derate above 25°C, at the following rates:

FE package at 6.2mW/°C

N package at 9.3mW/°C

D package at 6.2mW/°C

EC package at 10.0mW/°C

2. See "Power Dissipation Considerations" section.

DC ELECTRICAL CHARACTERISTICS at V_{CC} = 6V, Z_S = Z_L = Z_O = 50Ω and T_A = 25°C, in all packages, unless otherwise specified.

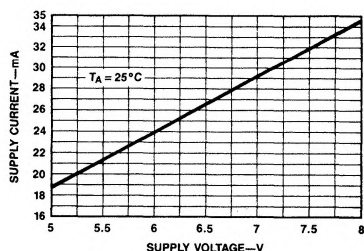
SYMBOL	PARAMETER	TEST CONDITIONS	SE5205			NE/SA/SE5205			UNIT
			Min	Typ	Max	Min	Typ	Max	
	Operating supply voltage range	Over temperature	5 5		6.5 6.5	5 5		8 8	V V
I _{CC}	Supply current	Over temperature	20 19	24	30 31	20 19	24	30 31	mA mA
S ₂₁	Insertion gain	f = 100MHz Over temperature	17 16.5	19	21 21.5	17 16.5	19	21 21.5	dB
S ₁₁	Input return loss	f = 100MHz D, N, FE		25			25		dB
		DC - f _{MAX} D, N, FE	12			12			dB
S ₁₁	Input return loss	f = 100MHz EC package					24		dB
		DC - f _{MAX} EC				10			dB
S ₂₂	Output return loss	f = 100MHz D, N, FE		27			27		dB
		DC - f _{MAX}	12			12			dB
S ₂₂	Output return loss	f = 100MHz EC package					26		dB
		DC - F _{MAX}				10			dB
S ₁₂	Isolation	f = 100MHz		-25			-25		dB
		DC - f _{MAX}	-18			-18			dB

Wide-band High-Frequency Amplifier

NE/SA/SE5205

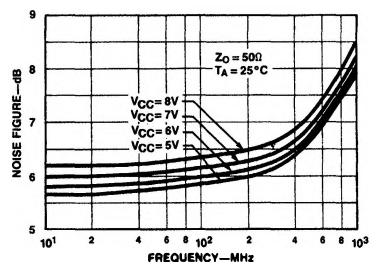
DC ELECTRICAL CHARACTERISTICS at $V_{CC} = 6V$, $Z_S = Z_L = Z_O = 50\Omega$ and $T_A = 25^\circ C$, in all packages, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	SE5205			NE/SA/SE5205			UNIT
			Min	Typ	Max	Min	Typ	Max	
BW	Bandwidth	$\pm 0.5dB$ D, N					450		MHz
f_{MAX}	Bandwidth	$-3dB$ D, N				550			MHz
f_{MAX}	Bandwidth	$\pm 0.5dB$ EC		300			500		MHz
f_{MAX}	Bandwidth	$\pm 0.5dB$ FE		300			300		MHz
f_{MAX}	Bandwidth	$-3dB$ EC				600			MHz
f_{MAX}	Bandwidth	$-3dB$ FE	400			400			MHz
	Noise figure (75 Ω)	$f = 100MHz$		4.8			4.8		dB
	Noise figure (50 Ω)	$f = 100MHz$		6.0			6.0		dB
	Saturated output power	$f = 100MHz$		+7.0			+7.0		dBm
	1dB gain compression	$f = 100MHz$		+4.0			+4.0		dBm
	Third-order intermodulation intercept (output)	$f = 100MHz$		+17			+17		dBm
	Second-order intermodulation intercept (output)	$f = 100MHz$		+24			+24		dBm



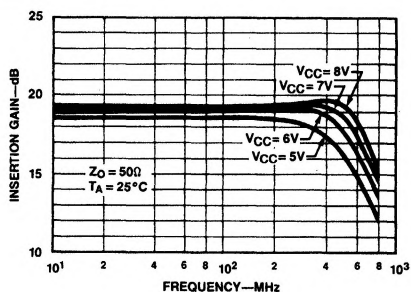
OP04640S

Figure 1. Supply Current vs Supply Voltage

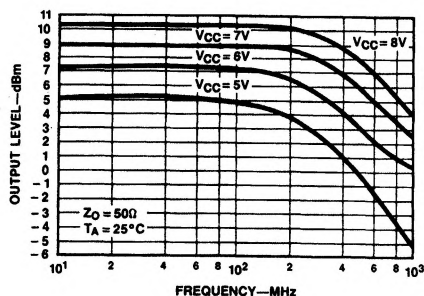


OP04650S

Figure 2. Noise Figure vs Frequency



OP04660S

Figure 3. Insertion Gain vs Frequency (S_{21})

OP04680S

Figure 4. Insertion Gain vs Frequency (S_{21})

Wide-band High-Frequency Amplifier

NE/SA/SE5205

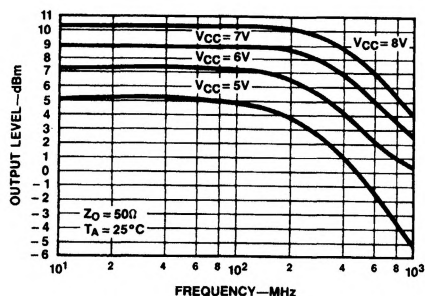


Figure 5. Saturated Output Power vs Frequency

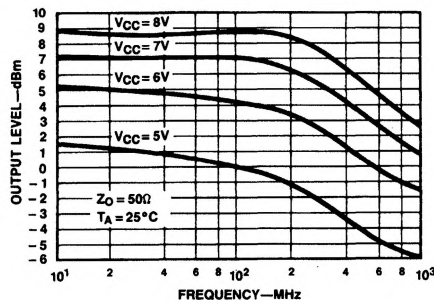


Figure 6. 1dB Gain Compression vs Frequency

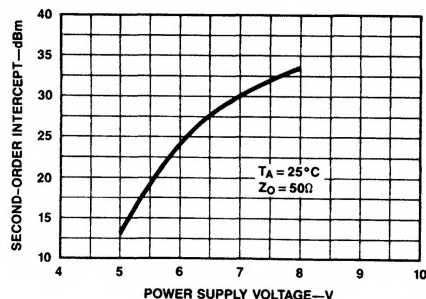


Figure 7. Second-Order Output Intercept vs Supply Voltage

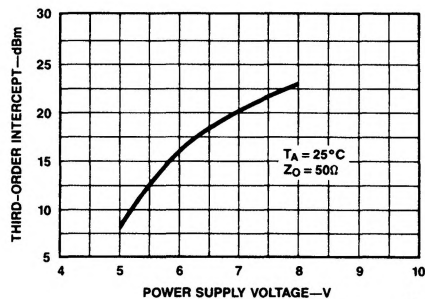


Figure 8. Third-Order Intercept vs Supply Voltage

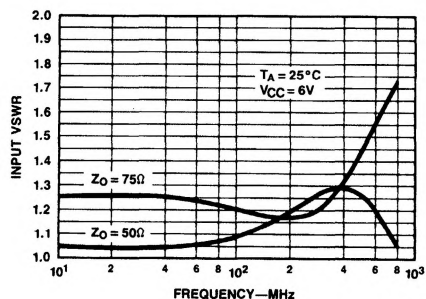


Figure 9. Input VSWR vs Frequency

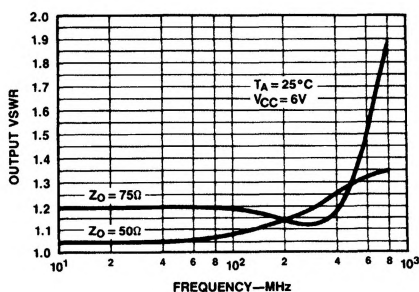
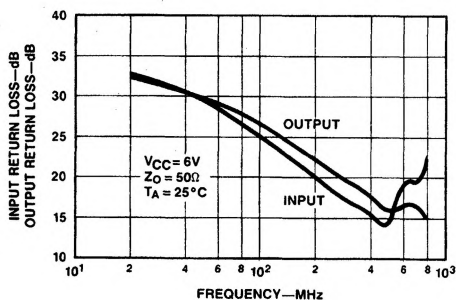


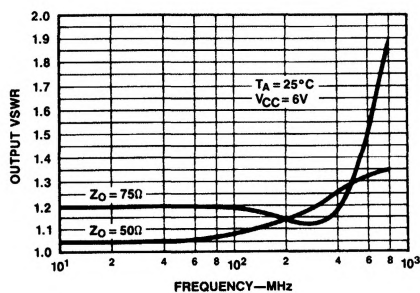
Figure 10. Output VSWR vs Frequency

Wide-band High-Frequency Amplifier

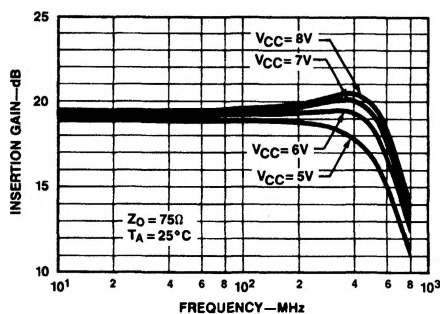
NE/SA/SE5205



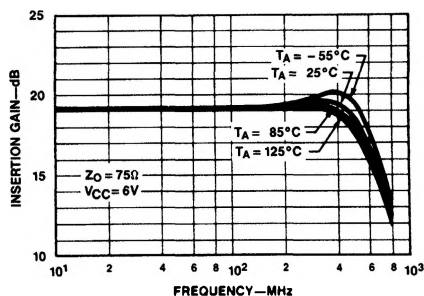
CP04740S

Figure 11. Input (S₁₁) and Output (S₂₂) Return Loss vs Frequency

OP04730S

Figure 12. Isolation vs Frequency (S₁₂)

CP04760S

Figure 13. Insertion Gain vs Frequency (S₂₁)

CP04770S

Figure 14. Insertion Gain vs Frequency (S₂₁)

Wide-band High-Frequency Amplifier

NE/SA/SE5205

THEORY OF OPERATION

The design is based on the use of multiple feedback loops to provide wide-band gain together with good noise figure and terminal impedance matches. Referring to the circuit schematic in Figure 15, the gain is set primarily by the equation:

$$\frac{V_{OUT}}{V_{IN}} = (R_{F1} + R_{E1}) / R_{E1} \quad (1)$$

which is series-shunt feedback. There is also shunt-series feedback due to R_{F2} and R_{E2} which aids in producing wideband terminal impedances without the need for low value input shunting resistors that would degrade the noise figure. For optimum noise performance, R_{E1} and the base resistance of Q_1 are kept as low as possible while R_{F2} is maximized.

The noise figure is given by the following equation:

$$NF = 10 \log \left\{ 1 + \frac{[r_b + R_{E1} + \frac{KT}{2qI_{C1}}]}{R_0} \right\} \text{ dB} \quad (2)$$

where $I_{C1} = 5.5\text{mA}$, $R_{E1} = 12\Omega$, $r_b = 130\Omega$, $KT/q = 26\text{mV}$ at 25°C and $R_0 = 50$ for a 50Ω system and 75 for a 75Ω system.

The DC input voltage level V_{IN} can be determined by the equation:

$$V_{IN} = V_{BE1} + (I_{C1} + I_{C3}) R_{E1}$$

where $R_{E1} = 12\Omega$, $V_{BE} = 0.8\text{V}$, $I_{C1} = 5\text{mA}$ and $I_{C3} = 7\text{mA}$ (currents rated at $V_{CC} = 6\text{V}$).

Under the above conditions, V_{IN} is approximately equal to 1V .

Level shifting is achieved by emitter-follower Q_3 and diode Q_4 which provide shunt feedback to the emitter of Q_1 via R_{F1} . The use of an emitter-follower buffer in this feedback loop essentially eliminates problems of shunt feedback loading on the output. The value of $R_{F1} = 140\Omega$ is chosen to give the desired nominal gain. The DC output voltage V_{OUT} can be determined by:

$$V_{OUT} = V_{CC} - (I_{C2} + I_{C6})R_2, \quad (4)$$

where $V_{CC} = 6\text{V}$, $R_2 = 225\Omega$, $I_{C2} = 7\text{mA}$ and $I_{C6} = 5\text{mA}$.

From here it can be seen that the output voltage is approximately 3.3V to give relatively equal positive and negative output swings. Diode Q_5 is included for bias purposes to allow direct coupling of R_{F2} to the base of Q_1 . The dual feedback loops stabilize the DC operating point of the amplifier.

The output stage is a Darlington pair (Q_6 and Q_2) which increases the DC bias voltage on the input stage (Q_1) to a more desirable value, and also increases the feedback loop gain. Resistor R_0 optimizes the output VSWR

(Voltage Standing Wave Ratio). Inductors L_1 and L_2 are bondwire and lead inductances which are roughly 3nH . These improve the high frequency impedance matches at input and output by partially resonating with 0.5pF of pad and package capacitance.

POWER DISSIPATION CONSIDERATIONS

When using the part at elevated temperature, the engineer should consider the power dissipation capabilities of each package.

At the nominal supply voltage of 6V , the typical supply current is 25mA (30mA Max). For operation at supply voltages other than 6V , see Figure 1 for I_{CC} versus V_{CC} curves. The supply current is inversely proportional to temperature and varies no more than 1mA between 25°C and either temperature extreme. The change is 0.1% per $^\circ\text{C}$ over the range.

The recommended operating temperature ranges are air-mount specifications. Better heat sinking benefits can be realized by mounting the D and EC package body against the PC board plane.

PC BOARD MOUNTING

In order to realize satisfactory mounting of the NE5205 to a PC board, certain techniques need to be utilized. The board must be double-sided with copper and all pins must be soldered to their respective areas (i.e., all

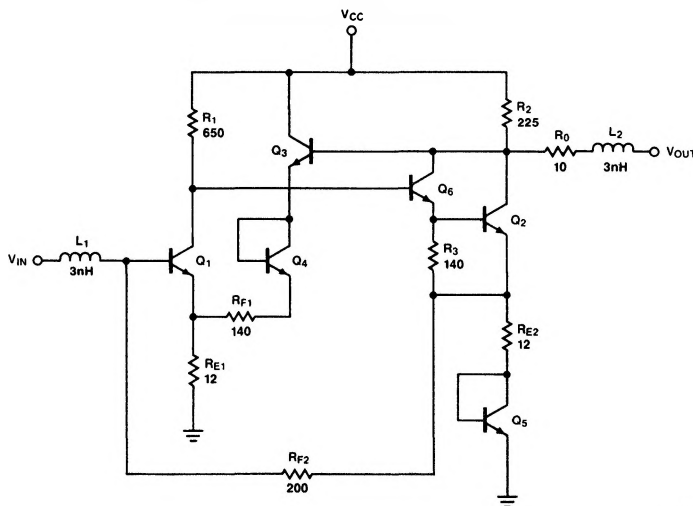


Figure 15. Schematic Diagram

TC085008

Wide-band High-Frequency Amplifier

NE/SA/SE5205

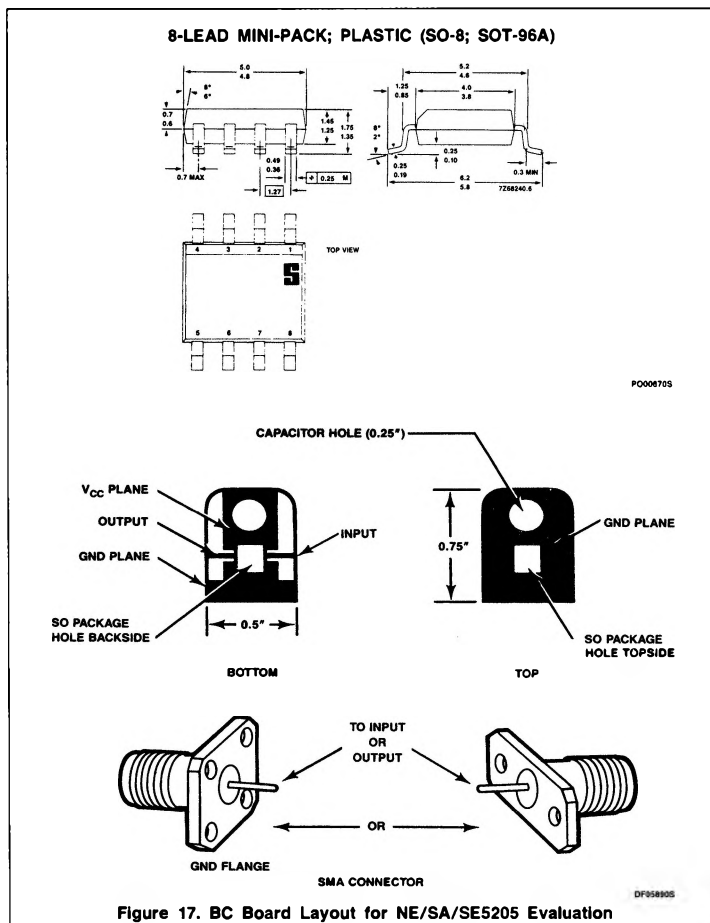
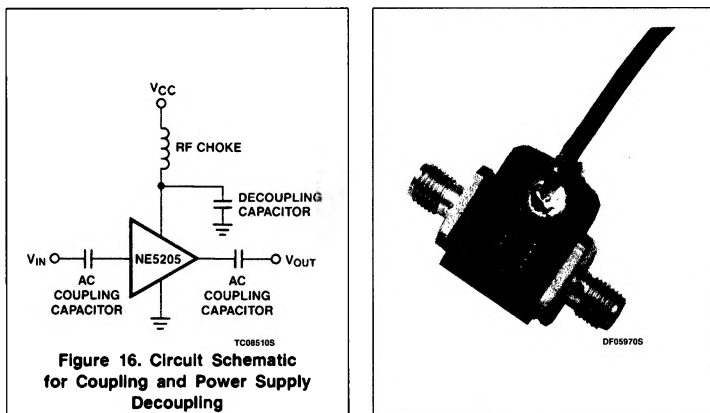
GND and V_{CC} pins on the SO package). In addition, if the EC package is used, the case should be soldered to the ground plane. The power supply should be decoupled with a capacitor as close to the V_{CC} pins as possible and an RF choke should be inserted between the supply and the device. Caution should be exercised in the connection of input and output pins. Standard microstrip should be observed wherever possible. There should be no solder bumps or burrs or any obstructions in the signal path to cause launching problems. The path should be as straight as possible and lead lengths as short as possible from the part to the cable connection. Another important consideration is that the input and output should be AC coupled. This is because at $V_{CC} = 6V$, the input is approximately at 1V while the output is at 3.3V. The output must be decoupled into a low impedance system or the DC bias on the output of the amplifier will be loaded down causing loss of output power. The easiest way to decouple the entire amplifier is by soldering a high frequency chip capacitor directly to the input and output pins of the device. This circuit is shown in Figure 16. Follow these recommendations to get the best frequency response and noise immunity. The board design is as important as the integrated circuit design itself.

Both of the evaluation boards that will be discussed next do not have input and output capacitors because it is assumed the user will use AC coupled test systems. Chip or foil capacitors can easily be inserted between the part and connector if the board trace is removed.

50 Ω EVALUATION BOARD

The evaluation board layout shown in Figure 17 produces excellent results. The board is to scale and is for the SO package but can be used for the EC package as well. Both top and bottom are copper clad and the ground planes are bonded together through 50 Ω SMA cable connectors. These are solder mounted on the sides of the board so that the signal traces line up straight to the connector signal pins.

Solid copper tubing is soldered through the flange holes between the two connectors for increased strength and grounding characteristics. Two or four hole flanges can be used. A flat round decoupling capacitor is placed in the board's round hole and soldered between the bottom V_{CC} plane and the top side ground. The capacitor is as thin or thinner than the PC board thickness and has insulation around its side to isolate V_{CC} and ground. The square hole is for the SO package which is put in upside down through the bottom of the board so that the leads are kept in



Wide-band High-Frequency Amplifier

NE/SA/SE5205

position for soldering. Both holes are just slightly larger than the capacitor and IC to provide for a tight fit.

This board should be tested in a system with 50Ω input and output impedance for correct operation.

75 Ω EVALUATION BOARD

Another evaluation board is shown in Figure 18. This system uses the same PC board as

presented in Figure 17, but makes use of 75 Ω female N-type connectors. The board is mounted in a nickel plated box* that is used to support the N-type connectors. This is an excellent way to test the part for cable TV applications. Again, the board should be tested in a system with 75 Ω input and output impedance for correct operation.

*The box and connectors are available as a "MOD-PACK SYSTEM" from the ANZAC division of

ADAMS-RUSSELL CO., INC., 80 Cambridge Street, Burlington, MA 01803.

SCATTERING PARAMETERS

The primary specifications for the NE/SA/SE5205 are listed as S-parameters. S-parameters are measurements of incident and reflected currents and voltages between the source, amplifier and load as well as transmission losses. The parameters for a two-port network are defined in Figure 19.

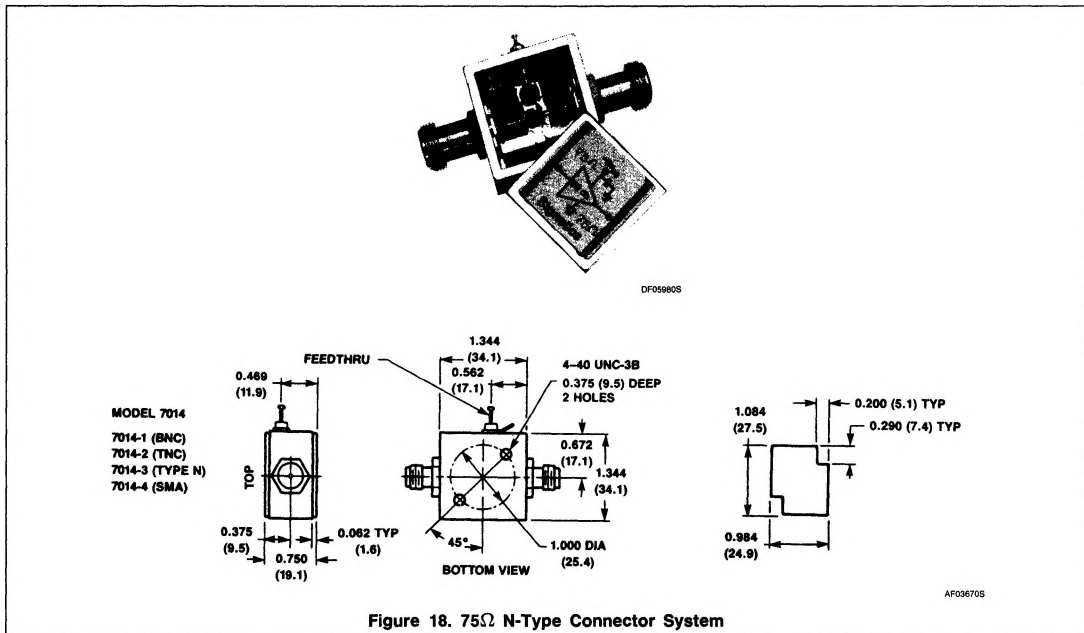


Figure 18. 75 Ω N-Type Connector System

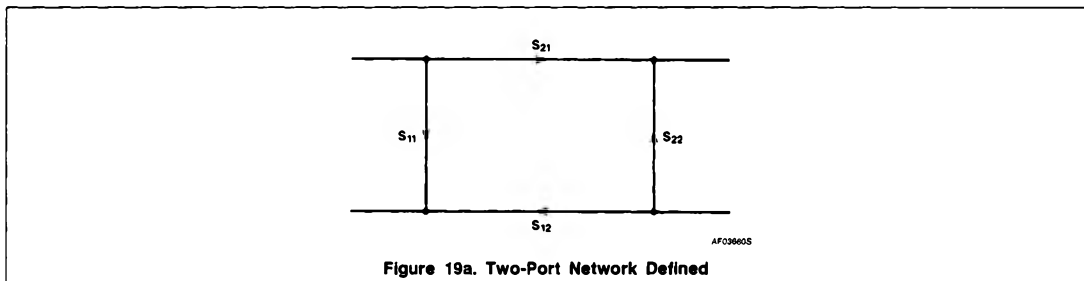


Figure 19a. Two-Port Network Defined

Wide-band High-Frequency Amplifier

NE/SA/SE5205

$$\begin{aligned}
 S_{11} &= \text{INPUT RETURN LOSS} \\
 S_{11} &= \sqrt{\frac{\text{POWER REFLECTED FROM INPUT PORT}}{\text{POWER AVAILABLE FROM GENERATOR AT INPUT PORT}}} \\
 S_{12} &= \text{REVERSE TRANSMISSION LOSS OR ISOLATION} \\
 S_{12} &= \sqrt{\frac{\text{REVERSE TRANSDUCER POWER GAIN}}{\text{POWER AVAILABLE FROM GENERATOR AT OUTPUT PORT}}} \\
 S_{21} &= \text{FORWARD TRANSMISSION LOSS OR INSERTION GAIN} \\
 S_{21} &= \sqrt{\text{TRANSDUCER POWER GAIN}} \\
 S_{22} &= \text{OUTPUT RETURN LOSS} \\
 S_{22} &= \sqrt{\frac{\text{POWER REFLECTED FROM OUTPUT PORT}}{\text{POWER AVAILABLE FROM GENERATOR AT OUTPUT PORT}}}
 \end{aligned}$$

Figure 19b

Actual S-parameter measurements using an HP network analyzer (model 8505A) and an HP S-parameter tester (models 8503A/B) are shown in Figure 20. These were obtained with the device mounted in a PC board as described in Figures 17 and 18.

For 50Ω system measurements, SMA connectors were used. The 75Ω data was obtained using N-connectors.

Values for the figures below are measured and specified in the data sheet to ease adaptation and comparison of the NE/SA/SE5205 to other high frequency amplifiers.

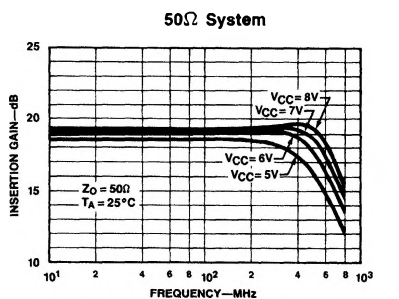
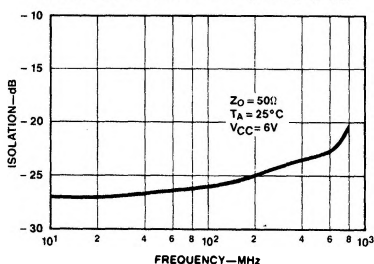
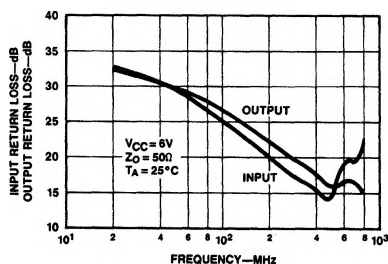
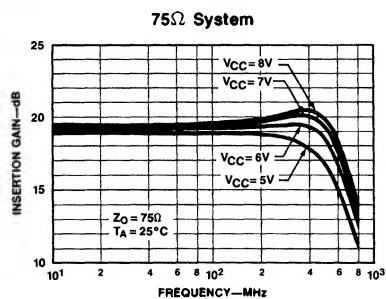
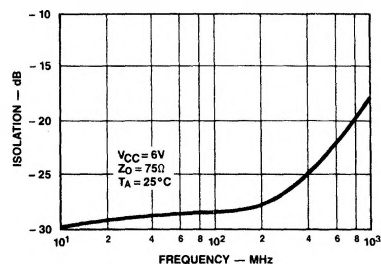
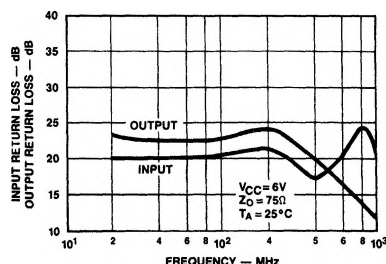
a. Insertion Gain vs Frequency (S_{21})c. Isolation vs Frequency (S_{12})e. Input (S_{11}) and Output (S_{22}) Return Loss vs Frequencyb. Insertion Gain vs Frequency (S_{21})d. S_{12} Isolation vs Frequencyf. Input (S_{11}) and Output (S_{22}) Return Loss vs Frequency

Figure 20

Wide-band High-Frequency Amplifier

NE/SA/SE5205

The most important parameter is S_{21} . It is defined as the square root of the power gain, and, in decibels, is equal to voltage gain as shown below:

$Z_D = Z_{IN} = Z_{OUT}$ for the NE/SA/SE5205

$$P_{IN} = \frac{V_{IN}^2}{Z_D} \quad \text{NE/SA/SE5205} \quad P_{OUT} = \frac{V_{OUT}^2}{Z_D}$$

$$\therefore \frac{P_{OUT}}{P_{IN}} = \frac{\frac{V_{OUT}^2}{Z_D}}{\frac{V_{IN}^2}{Z_D}} = \frac{V_{OUT}^2}{V_{IN}^2} = P_I$$

$$P_I = V_I^2$$

P_I = Insertion Power Gain

V_I = Insertion Voltage Gain

Measured value for the NE/SA/SE5205 = $|S_{21}|^2 = 100$

$$\therefore P_I = \frac{P_{OUT}}{P_{IN}} = |S_{21}|^2 = 100$$

$$\text{and } V_I = \frac{V_{OUT}}{V_{IN}} = \sqrt{P_I} = S_{21} = 10$$

In decibels:

$$P_{I(dB)} = 10 \log |S_{21}|^2 = 20\text{dB}$$

$$V_{I(dB)} = 20 \log S_{21} = 20\text{dB}$$

$$\therefore P_{I(dB)} = V_{I(dB)} = S_{21(dB)} = 20\text{dB}$$

Also measured on the same system are the respective voltage standing wave ratios. These are shown in Figure 21. The VSWR can be seen to be below 1.5 across the entire operational frequency range.

Relationships exist between the input and output return losses and the voltage standing wave ratios. These relationships are as follows:

$$\text{INPUT RETURN LOSS} = S_{11(dB)}$$

$$S_{11(dB)} = 20 \log |S_{11}|$$

$$\text{OUTPUT RETURN LOSS} = S_{22(dB)}$$

$$S_{22(dB)} = 20 \log |S_{22}|$$

$$\text{INPUT VSWR} = \frac{1 + |S_{11}|}{1 - |S_{11}|} \leq 1.5$$

$$\text{OUTPUT VSWR} = \frac{1 + |S_{22}|}{1 - |S_{22}|} \leq 1.5$$

1dB GAIN COMPRESSION AND SATURATED OUTPUT POWER

The 1dB gain compression is a measurement of the output power level where the small-signal insertion gain magnitude decreases 1dB from its low power value. The decrease is due to nonlinearities in the amplifier, an indication of the point of transition between small-signal operation and the large signal mode.

The saturated output power is a measure of the amplifier's ability to deliver power into an external load. It is the value of the amplifier's output power when the input is heavily overdriven. This includes the sum of the power in all harmonics.

INTERMODULATION INTERCEPT TESTS

The intermodulation intercept is an expression of the low level linearity of the amplifier. The intermodulation ratio is the difference in dB between the fundamental output signal level and the generated distortion product level. The relationship between intercept and intermodulation ratio is illustrated in Figure 22, which shows product output levels plotted versus the level of the fundamental output for two equal strength output signals at different frequencies. The upper line shows the fundamental output plotted against itself with a 1dB

to 1dB slope. The second and third order products lie below the fundamentals and exhibit a 2:1 and 3:1 slope, respectively.

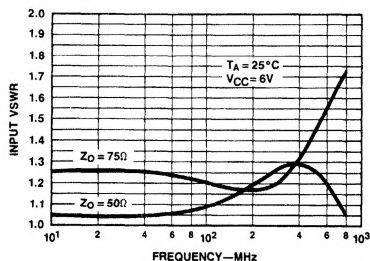
The intercept point for either product is the intersection of the extensions of the product curve with the fundamental output.

The intercept point is determined by measuring the intermodulation ratio at a single output level and projecting along the appropriate product slope to the point of intersection with the fundamental. When the intercept point is known, the intermodulation ratio can be determined by the reverse process. The second order IMR is equal to the difference between the second order intercept and the fundamental output level. The third order IMR is equal to twice the difference between the third order intercept and the fundamental output level. These are expressed as:

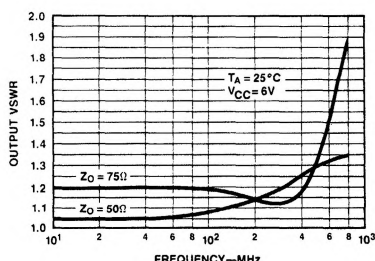
$$IP_2 = P_{OUT} + IMR_2$$

$$IP_3 = P_{OUT} + IMR_3/2$$

where P_{OUT} is the power level in dBm of each of a pair of equal level fundamental output signals, IP_2 and IP_3 are the second and third order output intercepts in dBm, and IMR_2 and IMR_3 are the second and third order intermodulation ratios in dB. The intermodulation intercept is an indicator of intermodulation performance only in the small signal operating range of the amplifier. Above some output level which is below the 1dB compression point, the active device moves into large-signal operation. At this point the intermodulation products no longer follow the straight line output slopes, and the intercept description is no longer valid. It is therefore important to measure IP_2 and IP_3 at output levels well below 1dB compression. One must be careful, however, not to select too low levels because the test equipment may not be able to recover the signal from the noise. For the NE/SA/SE5205 we have chosen an output level of -10.5dBm with fundamental frequencies of 100.000 and 100.01MHz, respectively.



a. Input VSWR vs Frequency



b. Output VSWR vs Frequency

Figure 21. Input/Output VSWR vs Frequency

Wide-band High-Frequency Amplifier

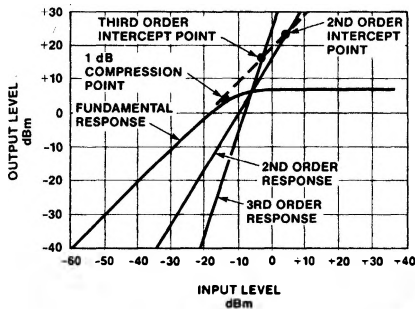
NE/SA/SE5205

**ADDITIONAL READING ON
SCATTERING PARAMETERS**

For more information regarding S-parameters, please refer to *High-Frequency Amplifiers* by Ralph S. Carson of the University of Missouri, Rolla, Copyright 1985; published by John Wiley & Sons, Inc.

"S-Parameter Techniques for Faster, More Accurate Network Design", HP App Note 95-1, Richard W. Anderson, 1967, HP Journal.

"S-Parameter Design", HP App Note 154, 1972.



DP04865

Figure 22